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PHYTOTOXICOLOGY 1995 and 1996

INVESTIGATIONS:

LIBBEY ST. CLAIR LIMITED

WALLACEBURG

SEPTEMBER 1998

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PHYTOTOXICOLOGY 1995 and 1996 INVESTIGATIONS:

LIBBEY ST. CLAIR LIMITED

WALLACEBURG

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Report No: SDB-007-3511-98

INTRODUCTION

Libbey-St.Clair manufactures glass and is located in a mixed industrial/residential area on Forhan Street South in Wallaceburg. The Phytotoxicology Section has conducted investigations of vegetation damage and foliar chemistry in the vicinity of the facility periodically since 1976. In each survey year, maple tree foliage (Manitoba, Norway and/or silver maple) was examined for contaminant-induced injury and analysed chemically. Abatement activities have apparently been successful in reducing the emissions of fluoride and chromium in recent years.

Foliar injury characteristic of boron toxicity was initially observed on Norway maple foliage at Site 10 immediately north of the facility in 1985 (see map page 6). Boron-type injury on maple foliage was observed at two sites in 1986 and 1987, one site in 1989, and four sites in 1992. The most severe injury has traditionally been observed at Site 10.

In 1995, the Sarnia District Office requested the assistance of the Phytotoxicology Section, Standards Development Branch, in the investigation of Libbey-St.Clair because of the suspected continuation of boron emissions. In 1995, concentrations of boron in tree foliage and the number of sites exceeding the ULN guideline increased markedly from the previous 1992 survey. In turn, the Sarnia District Office requested that the Phytotoxicology investigation be repeated in 1996. This report presents the results of the Phytotoxicology investigations in 1995 and 1996.

METHODOLOGY

On August 24, 1995, Phytotoxicology investigator C. Kinch collected tree foliage from twelve previously established sites in the area of Libbey-St Clair. Foliar inspections for boron-type injury also were conducted. The location of all sample sites is shown in Figure 1.

In 1996, Phytotoxicology investigator/author R. Emerson collected foliage and soil to determine if soil boron contamination had contributed to the elevated foliar levels in 1995. On July 11, soil from seven sites (Sites 1, 3, 5, 5a, 10, 15, 16) was collected at two depths (0-5 and 25-30 cm), except at Sites 3 and 5, where only surface soil was sampled due to hard-packed subsoil. Site 5a (new in 1996) was situated across the road from Site 5. On August 27, maple foliage from the same sites (1, 3, 5, 10, 15, 16), as well as Sites 4, 6 and 11, was collected. All samples were collected in duplicate using standard Phytotoxicology sampling procedures. Foliar inspections for boron-type injury were conducted in July and August.

The samples collected in both years were returned to the Phytotoxicology lab, where they were dried, ground and stored in glass jars. They were then submitted to the MOE Laboratory Services Branch for boron analysis. The 1996 foliage and soil samples were also analyzed for aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, fluoride, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, and zinc. In addition, the 1996 soils were analyzed for hot water extractable (HWE) boron.

Wind data normals were obtained from the closest Environment Canada monitoring station (Sarnia Airport - approximately 8 km NE of the centre of Sarnia) for the period from 1967 to 1980.

RESULTS and DISCUSSION

Annual wind normals revealed a strong tendency toward winds from the S (S and SSW) and from the W (W and WSW) during the growing season.

Foliar Injury

In August 1995, boron-type intercostal and marginal foliar injury was of moderate severity (11-35%) on the Norway maple at Site 10. Much less severe injury (trace 0-1%, or light 2-10%) was observed on the Norway maple at Site 1, Manitoba maple at Sites 3 and 15, and silver maple at Site 5. The elevated foliar boron concentration of Sites 1, 3 and 5 implicates boron as a contributing factor to the injury at these sample sites.

In August 1996, the foliar injury on the Norway maple at Site 10 was more suggestive of disease than boron injury. The silver maple at Sites 3 and 5 had boron-type tip or marginal foliar injury of mostly trace to light severity. These trees also were injured in July. The other collection sites in August had inconsequential injury or no injury, including the Manitoba maple at Site 3.

Chemical Analysis Results

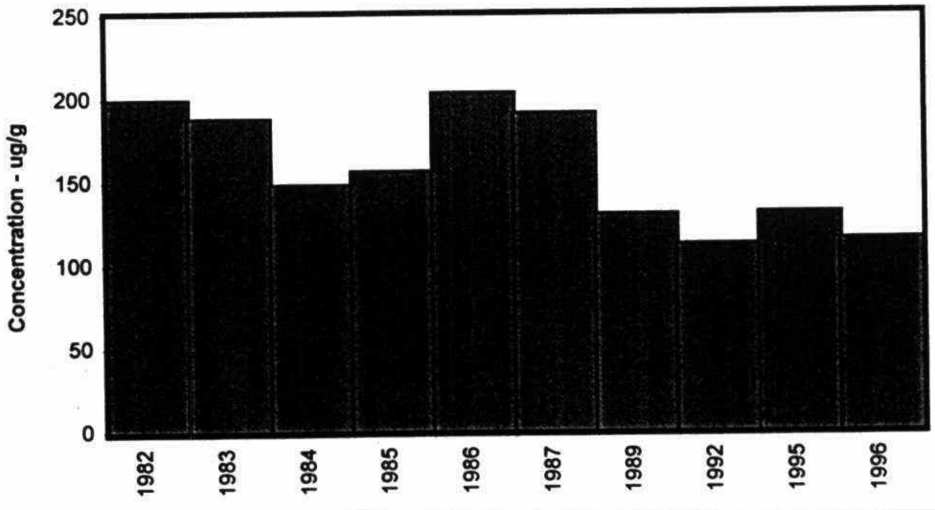
The foliar results are compared to the "Upper Limit of Normal" (ULN) urban guidelines. The soil results are compared to the "Ontario Typical Range" (OTR) and soil remediation (SR) guidelines. ULNs reflect the expected upper limit of normal concentrations in urban areas not influenced by point sources of emissions (see Appendix A). OTRs are similar to ULNs but they should more accurately reflect background levels because they are derived from a larger sample size. At this time, OTR's are only available for parkland soils (Appendix B). A level greater than the ULN or OTR indicates the likely presence of a contamination source. The SR guidelines are used for soil clean-up on contaminated properties when there has been a change in land use or ownership (Appendix C). They are effects-based numbers, which are based on human health (lead, cadmium), animals (copper, molybdenum) and plants (remaining elements). All results are reported as μg/g (micrograms per gram, commonly referred to as ppm or parts per million).

Total Boron and Metal Concentrations in Tree Foliage - 1995 and 1996

The 1995 and 1996 foliar boron results are compared with historical survey data in Table 1. In 1995, the boron ULN was exceeded at six foliage sites (1, 2, 3, 5, 7, 10) to the N, NE, E, and S of Libbey St. Clair, while only Site 3 (S) exceeded the ULN in 1996. The higher boron concentrations to the N and E are consistent with the prevailing wind directions.

In 1995, foliar boron levels throughout the survey area generally were higher than1992 (last survey conducted), particularly in the Manitoba maple at Site 3, some 780 m upwind to the south of the glassworks. At this site, the foliar boron level of the Manitoba maple (590 μg/g) was amongst the highest found in any maple species since 1982, when sampling was initiated. The boron level of the silver maple at Site 3 (285 μg/g) also was amongst the highest in silver maple in 1995. It has been over 10 years since Site 7 has exceeded the ULN, which it did in 1995. In 1996, foliar boron levels at all sites declined and only one sampling site (Site 3) exceeded the ULN. The sites common to all years (1982-1996) show a trend towards lower boron concentrations in recent years (illustrated in Figure 2 below). The mean boron concentration in 1996 (115 μg/g) was the second lowest, next to 1992 (111 μg/g).

Figure 2: Annual Mean Foliar Boron Concentration of Common Sample Sites - 1982 to 1996.



Because of the trend towards lower foliar boron levels up to 1992, the elevated levels in 1995 were surprising, especially at the more distant Site 3. It is likely that Libbey-St. Clair was still a boron source in1995, because the ULN was exceeded at several sites. However, as only Site 3 exceeded the ULN in 1996, with the sites much closer to the company having normal levels, Libbey-St. Clair was not likely a significant boron emission source in 1996. The normal foliar boron levels at all other sites in 1996 also indicates that there is not another source of atmospheric boron contributing to the foliar contamination in the survey area. This is supported by a recent moss bag study that was conducted from October to December, 1994 to address releases from the foundries just to the SW of Libbey St.Clair [Phytotoxicology Survey Report: Moss Bag Survey in the Vicinity of Benn Iron / Eaton Yale, Wallaceburg (1994) - SDB-016-3511-95]. The study indicated that Libbey St. Clair was the only industrial boron source in Libbey St. Clair survey area.

Table 2 summarizes the foliar results for all other elements, for which analysis were conducted, with the exception of beryllium, cadmium, cobalt, chromium and vanadium. These five elements were below analytical detection limits at all sites and have been excluded from the table. All elements listed in the table were within a normal range in relation to the ULN guidelines, with the exception of one sample tree at Site 16 that marginally exceeded the calcium ULN. The higher foliar levels of barium and strontium (ULNs not established) in the vicinity of Libbey-St. Clair are similar to those at the most distant collection site (Site 4).

Total Boron and Metal Concentrations in Soil - 1996

The soil chemical data are summarized in Table 3. The table shows that, at Sites 1, 5a, 10 and 15 (all close to Libbey-St. Clair), several elements, including boron, had a higher concentration in surface soil than at depth. This pattern is consistent with an atmospheric deposition source.

The highest total boron concentrations in surface soil were detected just west of Libbey St. Clair (Site 15), while most other elements tended to be higher at sample sites to the south (Sites 1, 3) or east (Sites 5, 5a). OTR guideline exceedances occurred for cadmium (Sites 3, 5, 5a, 15), copper (Sites 1, 5, 5a), fluoride (all sites), lead (Sites 3, 5, 5a), molybdenum (Sites 1, 3, 5), and zinc (Sites 1, 3, 5, 5a, 15). Historical emissions from Libbey-St. Clair likely are the major source of the elevated soil boron and fluoride concentrations.

With the exception of lead, soil concentrations of all elements that exceeded the OTRs were well below the effects-based soil remediation guidelines. A remediation guideline for fluoride has not been established. The soil lead concentrations of 235 μg/g (Site 5) and 265 μg/g (Site 5a) marginally exceeded the health-based guideline for lead (200 μg/g). However, soil lead concentrations in the 200-500 μg/g range are not unusual in old urban areas because of the historical use of leaded gasoline and leaded paints. Soil lead levels above 200 μg/g may present an increased health risk, especially for young children, but the level of risk depends on the degree of exposure.

Hot Water Extractable (HWE) Boron Concentrations in Soil - 1996

The MOE's current hot water boron extraction (HWE) method was used to determine the concentration of available boron in the soil. Boron in soil is water soluble and plant uptake can result in elevated foliar levels and foliar injury, even in the absence of elevated levels of boron in the ambient air. Concentrations above the HWE guideline of 1.5 μg/g are potentially injurious to sensitive plants. These results are compared with the other analytical data in Table 4.

Table 4 shows that surface soils have a slightly higher HWE boron concentration than subsoils. HWE boron in the surface soil at Site 3 (2.30 μg/g) and Site 5 (2.1 μg/g) exceeded the HWE guideline, an indication that soil contamination has contributed to the elevated foliar boron levels, particularly at Site 3. Sites 1 and 10 did not exceed the soil HWE boron guideline in 1996, but yet foliar boron levels were above the ULN in 1995. Because soil boron levels will not vary significantly in one year, this means that the elevated boron levels in foliage and the foliar injury observed in 1995 was caused by boron atmospheric emissions from Libbey-St. Clair in that year. Libbey-St. Clair is responsible for the soil boron contamination at Site 5, as this site is both very close to and downwind of the company.

CONCLUSIONS

In 1995, six foliage sites exceeded the ULN, indicating that Libbey-St. Clair was still a boron source in that year. In 1996, both foliar boron levels and boron foliar injury were reduced, indicating that the company probably emitted less boron to the atmosphere in 1996. Soil contamination was the likely source of the elevated foliar boron levels and/or foliar injury in 1996, particularly at Sites 3 and 5, as both sites had soil concentrations of HWE boron which exceeded the guideline. Even if Libbey-St. Clair has completely abated emissions of boron, vegetation close to the company will continue to have elevated foliar boron levels and possibly exhibit foliar injury symptoms because of boron uptake from contaminated soil. Soil boron levels should gradually decline over time from leaching by rainfall, providing that no further soil contamination occurs.

Figure 1: Sample Sites in the Vicinity of Libbey-St.Clair, Wallaceburg: 1995 and 1996.

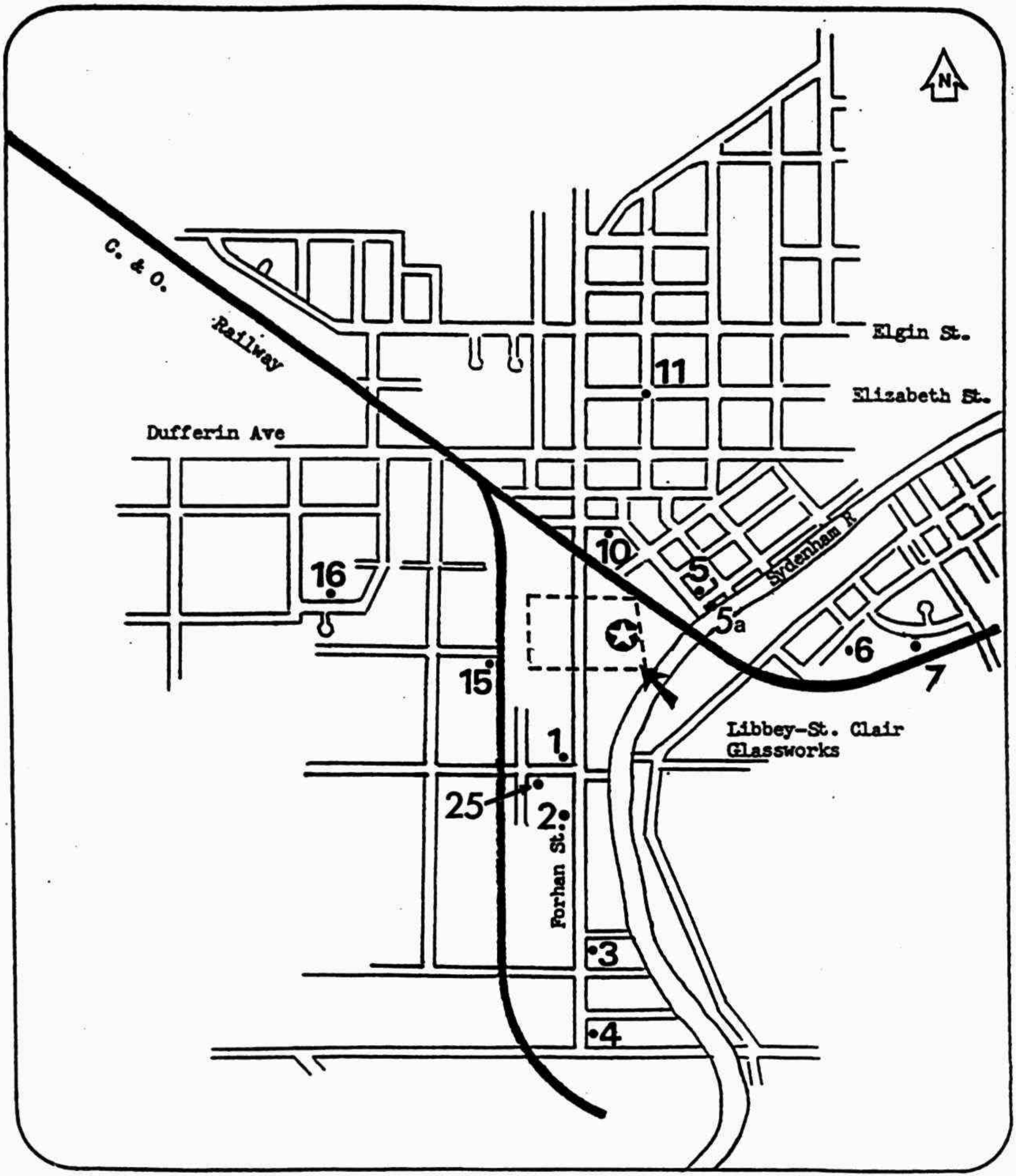


Table 1: Annual Boron Concentrations in Tree Foliage: Libbey-St.Clair, Wallaceburg - 1982 to 1996

Site	Maple Species	Distance & Direction from Libby	Boron Concentration* in Maple Foliage									
			1982	1983	1984	1985	1986	1987	1989	1992	1995	1996
1	Manitoba	240 m S	NA	NA	NA	NA	NA	NA	56	54	74	74
	Norway		170	**203**	**720**	**435**	**296**	**185**	NA	**180**	**195**	135
2	Silver	475 m S	175	103	96	92	121	100	78	72	105	NA
	Manitoba		135	140	120	145	**181**	165	**185**	120	**215**	NA
3	Silver	780 m S	160	147	155	140	164	NA	110	175	**285**	**180**
	Manitoba		NA	NA	NA	NA	NA	45	**245**	135	**590**	**255**
4	Silver	960 m S	105	117	**195**	90	54	105	49	38	48	NA
	Manitoba		140	127	**210**	125	135	**200**	78	76	89	90
5	Silver	180 m E	175	**183**	**180**	145	**183**	**195**	145	155	**205**	150
6	Silver	470 m E	65	71	66	41	66	85	83	44	82	NA
	Manitoba		140	90	97	105	68	135	89	68	130	89
7	Silver	700 m E	80	111	**195**	125	76	115	59	67	**185**	NA
	Manitoba		90	113	110	75	107	125	125	84	125	NA
10	Silver	300 m N	130	130	135	115	144	140	115	85	100	NA
	Manitoba		**450**	137	**320**	**215**	**229**	**255**	**190**	115	**220**	150
	Norway		125	**193**	145	150	**219**	155	**195**	150	135	145
11	Silver	560 m N	50	65	64	67	72	71	75	40	65	NA
	Norway		105	107	72	52	81	84	71	63	105	125
15	Manitoba	260 m W	**420**	**627**	125	**430**	**682**	**470**	**240**	**250**	125	150
16	Silver	680 m W	40	38	36	29	28	36	29	18	38	22
	Norway		NA	NA	NA	NA	NA	NA	NA	NA	NA	140
25	Silver	350 m S	NA	NA	NA	NA	NA	NA	25	32	55	NA
	Manitoba		**185**	170	**200**	135	125	**210**	**190**	85	100	NA
Mean of Common Sites**			**199**	**188**	**148**	**156**	**203**	**191**	**130**	**112**	**131**	**115**
ULN			175									

* ug/g, dry weight, mean of duplicate samples and analysis. ** Common Sites (4, 5, 6, 10, 11, 15).
ULN - " Upper Limit of Normal" urban guideline, see Appendix A. Note: Shaded results exceed ULN.. NA - Not available.

Table 2: Concentrations of Other Elements in Tree Foliage: Libbey-St. Clair, Wallaceburg (1996).

Site	Maple Foliage	Element / Concentration* in Foliage						
		Aluminum	Barium	Calcium	Copper	Fluoride	Iron	Lead
1	Manitoba	*38*	*15*	*28,000*	*4*	*6*	*130*	*1 T*
	Norway	*49*	*15*	*16,500*	*6*	*2 T*	*87*	*1 T*
3	Manitoba	*93*	*17*	*28,500*	*4*	*6*	*260*	*DL*
	Silver	*62*	*9*	*14,500*	*2T*	*7*	*155*	*1 T*
4	Manitoba	*55*	*15*	*25,000*	*10*	*7*	*145*	*1 T*
5	Silver	*56*	*9*	*13,000*	*7*	*9*	*125*	*2 T*
6	Manitoba	*66*	*16*	*26,500*	*4*	*6*	*160*	*2 T*
10	Manitoba	*38*	*16*	*29,000*	*4*	*4*	*96*	*1 T*
	Norway	*47*	*17*	*20,500*	*6*	*3*	*115*	*DL*
11	Norway	*26*	*12*	*22,500*	*9*	*2 T*	*80*	*1 T*
15	Manitoba	*61*	*13*	*24,500*	*6*	*13*	*150*	*2 T*
16	Norway	*61*	*15*	***33,500***	*7*	*3*	*103*	*1 T*
	Silver	*24 T*	*2*	*5,500*	*8*	*4*	*57*	*1 T*
ULN		*500*	*NG*	*30,000r*	*20*	*35*	*1,000*	*60*

*ug/g, dry weight, mean of duplicate samples and analysis. T - Trace amount. DL - At or below analytical detection limit.
Note: Underlined values exceed OTR
Note: Results shaded exceed urban ULN guideline, see appendix A. r - rural ULN (urban ULN not established). NG - ULN not established.

Table 2 Cont'd: Concentrations of Other Elements in Tree Foliage: Libbey-St. Clair, Wallaceburg (1996).

Site	Maple Foliage	Element / Concentration* in Foliage					
		Magnesium	**Manganese**	**Molybdenum**	**Nickel**	**Strontium**	**Zinc**
1	Manitoba	3,750	46	<1T	<1T	51	20
	Norway	1,250	15	<1T	2T	62	17
3	Manitoba	4,900	43	<1T	<1T	68	32
	Silver	3,150	16	DL	DL	33	33
4	Manitoba	3,300	23	<1T	<1T	50	26
5	Silver	2,150	13	DL	<1T	27	37
6	Manitoba	4,950	24	1T	DL	70	26
10	Manitoba	4,450	29	<1T	DL	63	21
	Norway	1,700	15	<1T	DL	39	27
11	Norway	2,150	13	DL	DL	32	17
15	Manitoba	4,250	22	<1T	DL	55	23
16	Norway	2,100	13	<1T	<1T	49	24
	Silver	1,550	6	DL	DL	10	18
ULN		7,000	100	1.5	7	NG	250

*ug/g, dry weight, mean of duplicate samples and analysis. T - Trace amount. DL - At or below analytical detection limit.
Note: Results shaded exceed urban ULN guideline, see Appendix A. r - rural ULN (urban ULN not established). NG - ULN not established.

Table 3: Concentration* of Boron and Other Elements in Soil at Each Site and Sample Depth (cm): Libbey-St. Clair, Wallaceburg (1996).

Element	**Site 1**		**Site 3**	**Site 5**	**Site 5a**		**Site 10**		**Site 15**		**Site 16**		**Guidelines**	
	0-5	**25-30**	**0-5**	**0-5**	**0-5**	**25-30**	**0-5**	**25-30**	**0-5**	**15-20**	**0-5**	**25-30**	**OTR**	**SR**
Aluminum	14,000	17,000	13,500	12,000	10,000	11,500	10,000	13,500	12,500	16,000	9,700	9,600	**27,000**	**NG**
Barium	90	94	140	135	125	140	86	110	105	81	51	48	**180**	**1,000**
Beryllium	0.7 T	0.8 T	0.7 T	0.6 T	DL	DL	DL	0.6 T	0.6 T	0.8 T	DL	DL	**0.9**	**1.2**
Boron	15	12	14	14	10	6	10	11	18	15	9	10	**30**	**NG**
Cadmium	0.8 T	0.7 T	**1.0** T	**2**	**1**	0.5 T	0.7 T	0.6 T	**1.1**	DL	0.5 T	0.3 T	**0.8**	**12**
Calcium	43,500	25,000	26,500	29,500	16,000	8,900	11,500	9,100	17,500	13,000	30,000	26,000	**58,000**	**NG**
Chromium	25	26	25	24	19	17	18	21	22	25	16	16	**62**	**1,000**
Cobalt	9	11	10	9	7	7	6	7	7	9	6	5	**17**	**50**
Copper	**67**	32	48	***105***	**78**	25	33	30	34	17	21	16	**65**	**300**
Fluoride	**84**	**81**	**93**	**240**	**130**	**96**	**115**	**115**	**103**	**93**	**89**	**98**	**42**	**NG**
Iron	19,500	22,500	19,500	17,500	14,000	13,500	14,000	16,000	17,000	22,000	12,000	11,500	**33,000**	**NG**
Lead	73	31	**144**	***235***	***265***	**110**	66	53	92	14	16	11	**98**	**200**
Magnesium	11,000	8,050	8,450	8,700	6,300	4,150	4,550	4,200	6,300	7,150	12,000	11,500	**16,000**	**NG**
Manganese	475	490	445	415	275	265	255	255	225	380	180	140	**1,300**	**NG**
Molybdenum	**1.4** T	0.7 T	**0.9** T	**1.1** T	0.7 T	DL	0.6 T	DL	DL	DL	0.7 T	DL	**0.85**	**40**
Nickel	27	25	25	31	22	15	17	24	20	25	17	15	**60**	**200**
Strontium	55	41	45	44	31	25	27	27	37	29	34	30	**78**	**NG**
Vanadium	33	38	34	30	28	27	27	31	31	39	25	25	**71**	**250**
Zinc	**195**	98	**240**	**325**	**185**	103	130	115	**205**	66	60	45	**140**	**800**

* ug/g, dry weight, mean of duplicate samples and analysis. DL - Concentration at or below analytical detection limit. T - Trace amount
OTR - "Ontario Typical Range" for urban parkland, see Appendix B. SR - Soil remediation guideline, see Appendix C. NG - Guideline not established. Note: Bold underlined results exceed guideline(s).

Table 4: Summary of 1996 Boron Levels in Soil and Foliage: Libbey-St. Clair, Wallaceburg.

Site	**Soil Concentration***			**Foliage Concentration***	
	Depth (cm)	**Total Boron**	**HWE Boron**	**Maple**	**Boron in Foliage**
1	0-5	15	0.9	Manitoba	74
	25-30	12	0.4	Norway	135
3	0-5	14	2.3	Silver	180
				Manitoba	255
5	0-5	14	*2.1*	Silver	150
5a	0-5	10	1.1	NR	NR
	25-30	6	1.0		
10	0-5	10	1.0	Norway	145
	25-30	11	0.7	Manitoba	150
15	0-5	*18*	1.4	Manitoba	150
	15-20	15	1		
16	0-5	9	0.8	Silver	22
	25-30	10	0.5	Norway	140
Guidelines		**30 (OTR)**	**1.5 (SR)**	**Guideline**	**175 (ULN)**

* ug/g, dry weight, mean of duplicate samples and analysis. HWE - Hot water extractable.
Note: Shaded results exceed guideline. NR - Samples not collected, no result. NG - Guideline not established.

Appendix A

Derivation and Significance of the MOE Phytotoxicology "Upper Limits of Normal" Contaminant Guidelines

The MOE Upper Limits of Normal (ULN) contaminant guidelines represent the expected maximum concentration in surface soil, foliage (trees and shrubs), grass, moss bags, and snow from areas in Ontario not exposed to the influence of a point source of pollution. Urban ULN guidelines are based on samples collected from developed urban centres, whereas rural ULN guidelines were developed from non-urbanized areas. Samples were collected by Phytotoxicology staff using standard sampling procedures (ref: Ontario Ministry of the Environment 1983, *Phytotoxicology Field Investigation Manual*). Chemical analyses were conducted by the MOE Laboratory Services Branch.

The ULN is the arithmetic mean, plus three standard deviations of the mean, of the suitable background data. This represents 99% of the sample population. This means that for every 100 samples which have not been exposed to a point source of pollution, 99 will fall within the ULN.

The ULN do not represent maximum desirable or allowable limits. Rather, they are an indication that concentrations that exceed the ULN may be the result of contamination from a pollution source. Concentrations that exceed the ULN are not necessarily toxic to plants, animals, or people. Concentrations that are below the ULN are not known to be toxic.

ULN are not available for all elements. This is because some elements have a very large range in the natural environment and the ULN, calculated as the mean plus three standard deviations, would be unrealistically high. Also, for some elements, insufficient background data is available to confidently calculate ULN. The MOE Phytotoxicology ULN are constantly being reviewed as the background environmental data base is expanded. This will result in more ULN being established and may amend existing ULN.

Appendix B

Derivation and Significance of the MOE "Ontario Typical Range" Soil Guidelines.

The MOE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline number*) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes green belts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.*

Appendix C

Derivation and Significance of the MOE Soil Remediation Criteria (Clean-up Guidelines)

The MOE Soil Remediation Criteria have been developed to provide guidance in cleaning up contaminated soil. They are not action levels, in that an exceedence of one or more of the criteria does not automatically mean that a clean-up must be conducted. A site clean-up may be conducted when a contaminated property is sold and/or the land use is changed. For example, the owner of an industrial property who plans to sell his/her land to a developer who intends to build residential homes can use the Remediation Criteria to clean up the soil to meet the residential land use criteria. This will allow the site to be reused for residential land-use without concern for adverse effects.

When contamination is found at a site where a change in land-use is not planned, the criteria may be used to assist in making decisions about adverse effects and the need for remediation. This is different from the previously described situation where a decision to change the land-use has already been made and the level of remediation required to rule out the potential for adverse effects is established by the new land use. Decisions on the need to undertake remedial action when the criteria are exceeded, and where the land use is not changing, require consideration of factors such as:

- the demonstrated presence or likelihood of an adverse effect (on and off property);
- an understanding of the type of protection provided by the criteria gained through knowledge of the exposure pathways and receptors which were considered in the development of the criteria, and through understanding how that combination of pathways and receptors relate to those which could be found at the site;
- an understanding of the relationship between dose and health response for sensitive receptors from all exposure pathways, including the safety and uncertainty factors that have been used in the development of the criteria;
- an understanding of the environmental characteristics of the contaminants and of the site conditions that could influence the migration of the contaminants and how this effects their exposure and response characteristics.

In each case, the decision to undertake or not undertake site remediation should entail all of these factors plus any additional factors specific to the site in question. When the decision is made that remedial action is needed, the criteria can be used as clean-up targets. If these criteria are unacceptable to the proponent undertaking the remediation, they have an option to develop local back-ground-based criteria or conduct a site specific risk assessment.

The Soil Remediation Criteria are effects-based concentrations set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. There are different Soil Remediation Criteria for soil texture, soil depth, and ground water use. The criteria have also been established so that there will not be a potential for adverse effects through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, use of these criteria may not ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

The Soil Remediation Criteria were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of Soil Remediation Criteria is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing criteria.

For more information on the Remediation Criteria please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised December 1996*, Ontario Ministry of Environment, PIBs 3161E01, ISBN 0-7778-5905-X.

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